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MECHANICAL CHARACTERIZATION AND WEAR BEHAVIOUR OF AL7075 ALLOY REINFORCED WITH ALUMINA AND MOLYBDENUM DISULPHIDE

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ABSTRACT

Aluminium based hybrid metal matrix composites (MMC's) are widely used in aerospace, automobile, transportation, marine, mineral processing and electrical packaging industries, because these composites exhibit low density, high specific strength and stiffness, high conductivity and corrosion resistance. In this work, an attempt has been made to reinforce the alumina(4, 8, 12 wt.%) and moybdenum disulphide(2, 4, 6 wt.%) with Al7075 alloy to improve mechanical and tribological behaviour of the hybridMMC's. Microstructural analysis of the hybrid composite specimens were carried under metallurgical microscope to decide uniform distribution and good bonding of Al_2O_3 and MoS_2 reinforcement with aluminium matrix. Prepared hybrid composite specimens will undergo mechanical and wear testing to evaluate its hardness, tensile strength, percentage of elongation and wear rate.

***KEYWORDS:** Al7075, Stir casting, Alumina, Molybdenum Disulphide, Mechanical Properties & Wear Rate*

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Original Article

1. INTRODUCTION

Metal matrix composites (MMC's) are the engineering materials, which possess the ability to tailor their physical, mechanical and tribological properties for given application. These MMC's will replace the conventional engineering materials in many applications such as bearings, brake pads, pistons and cylinder liners etc [1]. Over the last few decades, continuous research has been going on to develop Aluminium based MMCs with high strength to light weight, stiffness, wear resistant and corrosion resistant materials, especially for automobile and aerospace industries. Aluminium is widely used as base material for composite fabrication, as it is having low density, high strength to weight ratio, corrosion resistance and good castability. Various type of hard ceramic particles such as SiC [2-7], Al_2O_3 [8-12], TiC [13-14] and ZrO_2 [15-16] etc. are used as reinforcement materials for different application. Among these major reinforcements, Alumina reinforced composites give high hardness, tensile strength and wear resistance of the composites. Increase in the volume fraction of alumina in the Aluminium alloy increases tensile strength, hardness and wear resistance of the composites[17]. But, significant increase in the hardness makes difficult to machine material [18]. Addition of solid lubricant like Graphene (Gr) or molybdenum disulphide (MoS_2) to the reinforcement particles improve the wear resistance of the composites [19-21]. This is due to the formation of lubricant film which decreases friction coefficient [22-23]. Increase in the

weight fraction of MoS_2 decreases the hardness of the composites due to increased porosity[24]. So, there should be certain limit to add the solid lubricants to the unreinforced alloy along with the reinforcement particles to decrease the wear rate. Gr is added as the reinforcement in various studies as it possess better self lubricating properties. But, there is a meager data available on the MoS_2 reinforced composites, which also exhibits self lubricating nature. The major advantage of MoS_2 over the Gr is that, it can be used in vacuum also, as it does not require any external support. The main aim of the present study is to fabricate the hybrid composite of Al7075 alloy reinforced with various wt.% of Al_2O_3 and MoS_2 particles and to study mechanical and tribological properties.

2. EXPERIMENTAL DETAILS

2.1 Materials

Aluminim 7075 alloy used as a matrix material with zinc as the primary alloying agent. The chemical composition and properties of Al7075 alloy is shown in Table 2.1-(a-b), respectively.

Table 2.1 (a): Chemical Composition of Al7075 Alloy by Weight Percentage

Composition	Zn	Mg	Cu	Fe	Si	Mn	Ti	Cr	Al
Wt.%	5.5	2.5	1.6	0.5	0.4	0.3	0.2	0.15	Remaining

Table 2.1 (b): Properties of Matrix Material

Properties	Al7075
Density(g/cc)	2.81
Elastic modulus(GPa)	70-80
Poissons ratio	0.33
Hardenss	60
Tensile strength (MPa)	220

Figure 2.1 (a): Alumina Powder

Figure 2.1 (b): MoS_2 Powder

Alumina having density 3.89 g/cc and molybdenum disulphide having density 5.06 g/cc are selected as the reinforcement material. Figure 2.1-(a-b) shows Al_2O_3(average size of 40 µm) and MoS_2 (average size around 2-4 µm) powders.

2.2 Hybrid Composite Preparation

Al7075- Al_2O_3 - MoS_2 hybrid MMC's were prepared by reinforcing the aluminium with alumina along with MoS_2 by stir casting method. Initially, 500 gm of commercially available pure Al7075 was melted in a resistance heated muffle furnace up to 973K and casted in a cast iron crucible. Next step involves preheated alumina(4,8 and 12 wt.%) and

molybdenum disulphide(2,4 and 6 wt.%) were added to the aluminium melt for production of three different composites. Magnesium was added in order to increase the wettability between the matrix and the reinforcements. The melt temperature was maintained at 943K-973K during the addition of the particles and the stirrer speed is maintained at 250-300 rpm. Then, the melt was casted in a cast iron crucible. Figure 1 and Figure 2 shows stir casting setup and casted hybrid composites having dimensions$10 \times 10 \times 1$ cm^3. Figure 2.2-(a-b) shows the stir casting setup used and the fabricated hybrid composites.

In this paper, sample 1 contains pure Al7075, sample 2 contains Al7075-4 wt.% Al_2O_3-2 wt.% MoS_2, sample 3 contains Al7075-8 wt.% Al_2O_3-4 wt.% MoS_2, sample 4 contains Al7075-12 wt.% Al_2O_3-6 wt.% MoS_2.

Figure 2.2 (a): Stir Casting Setup

Figure 2.2 (b): Casted Composites

2.3 Testing of Hybrid Composites

2.3.1 Characterizatoin

Actual density of the hybrid composites were calculated by using Archimedes principle, in which the hybrid composites were immersed in the water to find its volume, by calculating the rise in water level. From the measured volume and mass, actual density was calculated. Microstructure of the hybrid composites were examined by using Metascope metallurgical microscope having 100X magnification by preparing specimens, according to the ASTM E407 standard. Prior to this, surfaces of the specimens will undergo series of grinding and polishing steps to achieve mirror like surface finish. The specimens were subsequently etched using 2%HF reagent by swabbing 10-20 sec, before the microstructural examination.

2.3.2 Hardness test

Hardness of the composites were evaluated by using Brinell hardness tester. The diameter of the steel ball indentor was 16 mm. A test load of 100 Kgf is applied to the specimens for 15s. An average of the three readings was taken for each sample to measure hardness of the hybrid composites.

2.3.3 Tensile test

The tensile specimens were prepared according to the ASTM E8M04, using wire cut EDM process. The test was performed with samples in the automated servo-hydraulic testing machine (Instron 1123) having capacity of 25kN with a strain rate 1mm/min.

2.3.4 Wear Test

Pin on disc machine is used to study the dry sliding wear behaviour of hybrid composites. Wear test specimens having length 30 mm and width 3 to 12 mm having thickness 6 mm is prepared using wire cut EDM. Initially, the surfaces of the pin samples of each hybrid composite were slided using emery paper, in order to achieve flat contact between the sample and the steel disc. Before the test, pin sample and disc were cleaned with ethanol soaked cotton. In the present study, the parameters such as sliding speed 3 m/s, normal load 19.62 N and sliding distance 3000 m were kept constant for the time duaration of 16.67 minutes.

3. RESULTS AND DISCUSSIONS

3.1 Density Studies

Figure 3.1 shows the values of theoretical and experimental densities. Theoretical density was calculated by rule of mixtures and the experimental density was calculated by Archimedes principle. Theoretical and actual densities are inline with each other, this confirms fabrication of hybrid composites by stir casting was successfully done. As the reinforcement content in the base matrix increases, density of the composites increases. The main reason for increase in the density of the composites is reinforcement material alumina and moylbdenum disulphide posses higher density values.

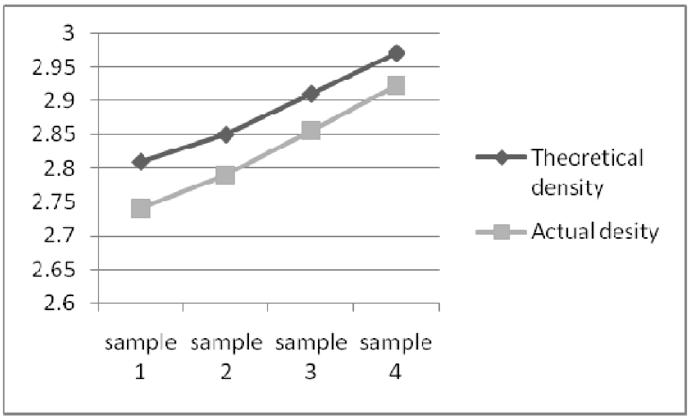
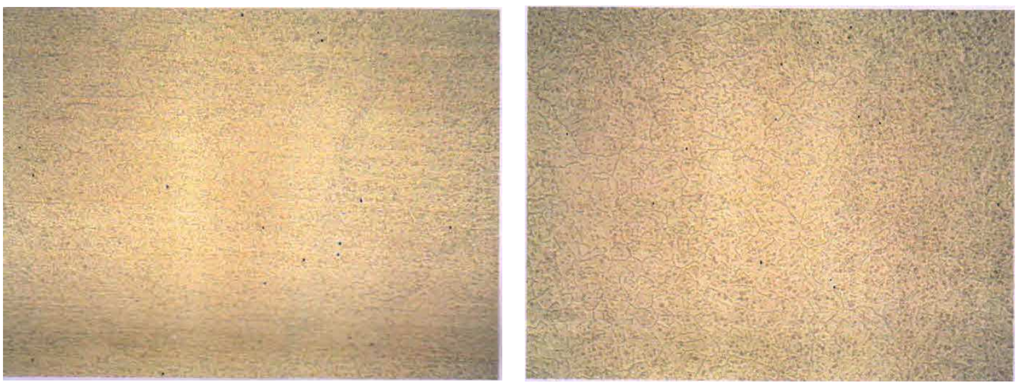
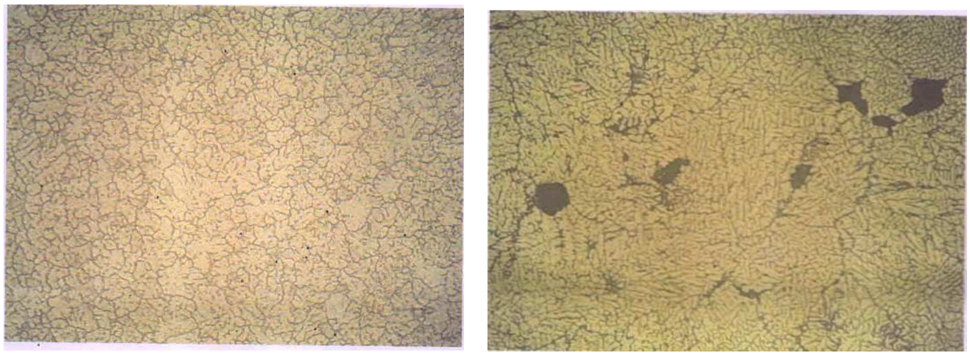


Figure 3.1: Comparison of Theoretical and Experimental Density Values with wt. % of Composition

3.2 Microstructural Study



(a) **(b)**



(c) (d)

Figure 3.2(a-d): Showing the Microstucture of Al7075 Alloy Before and After Addition of Al_2O_3 and MoS_2 Particulates(a) Al7075 Alloy (b) Al7075-4 wt.% Al_2O_3-2 wt.% MoS_2 (c) Al7075-8 wt.% Al_2O_3-4 wt.% MoS_2 (d) Al7075-12 wt.% Al_2O_3-6 wt.% MoS_2

Figure 3.2-(a) shows the characteristics of the Al7075 alloy, where as figure 3.2-(b-c) shows the uniform distribution of the reinforcement particulates that is alumina and molybdenum disulphide in the matrix material. But, further increase in the weight fraction of alumina and molybdenum disulphide agglomeration takes place at some places as shown in figure 3.2-(d). This may be due to the low solubility of the reinforcements and large density differences between the matrix and reinforcements.

3.3 Hardness Test Results

From the figure 3.3, the maximum hardness value 99.6 BHN for sample 4, that isAl7075-8 wt.% Al_2O_3-4 wt.% MoS_2. We can observe tha, t the hardness of the hybrid composites is greater than the hardness of the unreinforced alloy. This is due to incorporation of hard ceramic particles of alumina in the base alloy increases the hardness of the of the hybrid composites. For sample 4, that is Al7075-12 wt.% Al_2O_3-6 wt.% MoS_2, there was a slight decrease in the hardness found. This may be due to the porosity present in the sample and presence of more weight fraction of MoS_2.

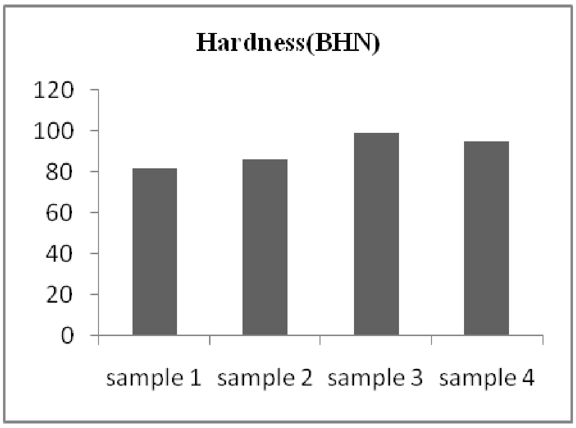


Figure 3.3: Variation of Hardness Values with wt. % of Composition

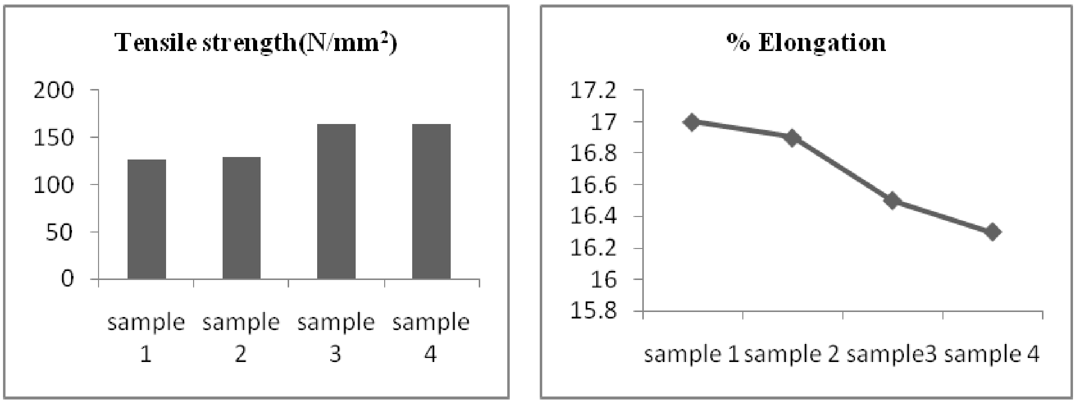
3.4 Tensile Test Results

From the table 3.4, the maximum tensile strength 165.06 N/mm^2 for sample 4, that is Al7075- 12% Al_2O_3-6% MoS_2, which is increased about 39MPa (30.52%) compared to the base alloy. We can observe that the tensile strength of the hybrid composites is greater than the tensile strength of the un reinforced alloy.

Table 3.4: Tensile Test Results on Al7075-Al_2O_3-MoS_2 Hybrid Composits

S. No	Composition	Ultimate Tesile Strength (MPa)	Modulus of Elasticity (Kg/cm^2)	Percentage Increase in UTS Value (%)
1	Sample 1	126.46	1378.9	-
2	Sample 2	129.03	1760.4	2.03
3	Sample 3	163.96	1753.3	29.65
4	Sample 4	165.06	1760.4	30.52

Increase in the tensile strength is due to the transfer of load from the matrix material to the reinforcement material. From the figure 4.4-(b), the percentage of elongation values are decreasing in nature due to the presence of hard ceramic particles of alumina in the matrix. The reduction in the percent of elongation values are lower due to the presence of moybdenum disulphide, which is of soft in nature promotes ductility.



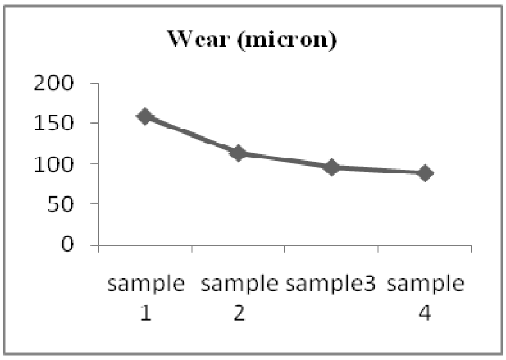
(a) (b)

Figure 3.4

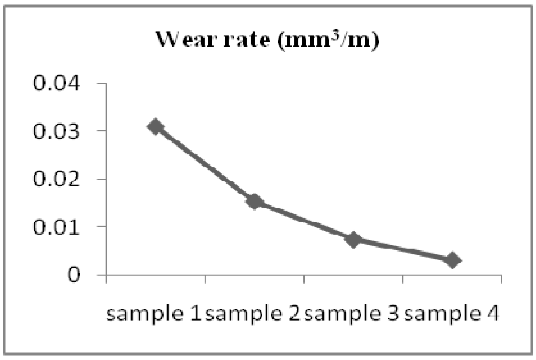
Figure 3.4-(a-b) showing the tensile test results of Al7075 alloy before and after addition of $Al_2O_3$and MoS_2 particulates(a) variation in ultimate Tensile strength with wt% of composition (b) variation in % Elongation with wt% of composition.

3.5 Wear Test Results

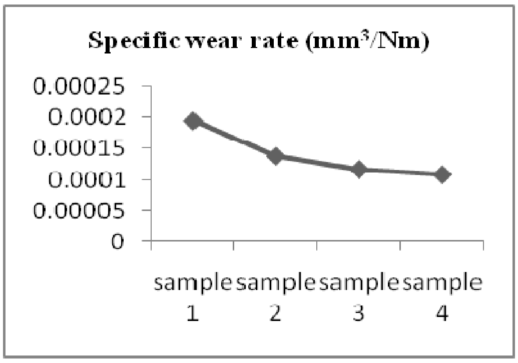
Wear rate is minimum for sample 4, that is for Al7075- 12% Al_2O_3-6% MoS_2 and maximum for sample 1, that is for unreinforced Al7075 alloy. Wear resistance of the hybrid composites increases as the reinforcement content alumina and molybdenum disulphide content increases. The presence of MoS_2 which is stable forms the mechanically mixed layer, which prevents the metal to metal contact, thus the wear resistance of the composites increases. If the abscence of solid lubricant is unstable, mechanically mixed layer will form, which tend to decrase the wear resistance of the composites.



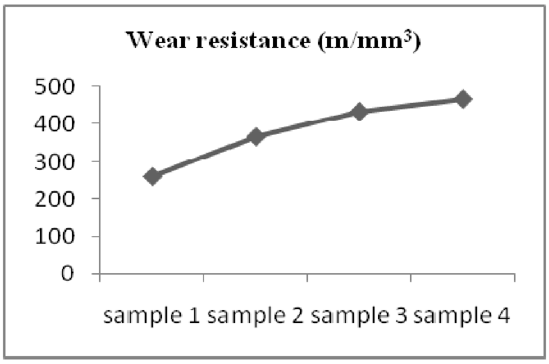
(a)



(b)



(c)



(d)

Figure 3.5

Figure 3.5-(a-d) showing the wear test results of Al7075 alloy before and after addition of $Al_2O_3$and MoS_2 particulates(a) variation in wear with wt% of composition (b) variation in wear rate with wt% of composition (c) variation in specific wear rate with wt% of composition (d) variation in wear resistance with wt% of composition.

4. CONCLUSIONS

The following conclusions are drawn after conducting the microstructural analysis, hardness test, tensile test and wear test on the hybrid composites.

- Al7075-Al_2O_3-MoS_2 hybrid composites were successfully fabricated by using stir casting technique.
- The theoretical and experimental densities are inline with each other. The density of the hybrid composites increases as the alumina and molybdenum disulphide weight fraction increases in the base matrix.
- The microstructural studies revealed that, uniform distribution of the alumina and molybdenum disulphide particles inthe Al7075 alloy matrix was observed for all the composites, except for sample 4 that is Al7075-12% Al_2O_3-6%MoS_2, because of the presence of undissolved MoS_2particles in the base alloy.
- The hardness test revealed that, the fabricated hybrid composites exhibit higher hardness values than the base alloy. The maximum hardness 99.6 BHN was found in the sample 3, that is Al7075-8% Al_2O_3-4%MoS_2. Due to the presence of more weight fraction, MoS_2decreases the hardness in sample 4.

- Tensile test results show that the fabricated hybrid composites exhibit higher tensile strength values than the base alloy. The maximum tensile strength 165.06 MPa was observed in the sample 4, that is Al7075-12% Al_2O_3-6%MoS_2.
- The percentage of elongation value decreases as the alumina content increases in the base alloy.
- From the wear test results, decrease in the wear loss of the hybrid composites clearly indicate that the hybrid composites exhibit better wear resistance than the base alloy.

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